

Sea Turtle Nesting Trends at Kennedy Space Center and Cape Canaveral Air Force Station, Florida, and Relationships with Factors Influencing Nest Site Selection

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ABSTRACT

Baseline marine turtle nesting data, for the loggerhead turtle, *Caretta caretta*, in particular, have been collected at the Kennedy Space Center (KSC) since 1973 to assess the relative importance of the KSC beach in the maintenance of marine turtle populations in the southeastern United States. The data provide a monitoring tool for impact assessment related to the Space Transportation System operations at KSC. Marine turtle crawl counts conducted 1979 to 1984 on the 34-km study beach along KSC and Cape Canaveral Air Force Station demonstrate that high and low nest densities are consistently concentrated in two regions. The high and low nest density areas had significantly different means ($P < 0.05$) of 94 nests/km and 39 nests/km, respectively, in 1984. Nest densities were compared with physical parameters of the beach face and nearshore zone. Total crawls were positively correlated with beach face slope ($r = 0.86$), with slopes ranging from 3.0° to 12.5° , and negatively correlated with beach width ($r = -0.79$). Nearshore contours influence beach slope and may influence nest site selection. Yearly nest density estimates ranged from 30 (1980) to 106 (1983) nests per km.

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INTRODUCTION

Baseline data collection, involving marine turtles along the coast of the Kennedy Space Center (KSC) and Cape Canaveral, Florida, was initiated in 1973 as part of NASA funded ecological studies required for the preparation of an environmental impact statement for the KSC. Prior to 1973, information regarding the status of marine turtles nesting along the expansive government-owned portion of the eastern Florida coast was virtually unknown or at least unpublished in the scientific literature (Ehrhart 1976). Preliminary research included tagging and measuring nesting females. Major baseline activities involving a variety of sea turtle research projects continued through 1979 to provide an assessment of the relative importance of the KSC area in the maintenance of sea turtle populations of the southeastern United States. They also provided baseline data against which subsequent studies, performed after the initiation of space shuttle launches, could be compared for impact assessment. Turtle tagging operations continued through the 1981 nesting season.

Carr and Carr (1977) established that the beach at KSC and the Cape Canaveral Air Force Station (CCAFS) is a primary rookery in the southeastern United States for the loggerhead turtle (*Caretta caretta*). Carr et al. (1982) reported that the Florida east coast nesting population is the largest within its range in the western hemisphere (Fig. 1). Aerial pelagic surveys of marine turtles indicated that loggerhead densities are greater in the vicinity of Cape Canaveral in the spring and summer than anywhere else along the entire U.S. Atlantic coast (Thompson and Powers 1985).

Realizing the importance of this beach, sea turtle crawl surveys were initiated in 1983 to document the distribution of sea turtle nests and activities along the secured KSC-CCAFS beach. The objective was to quantitatively compare crawl activities (i.e., nest densities) in areas adjacent to the Space Transportation System (STS) Launch Complex (LC) 39A with activities observed in nearby isolated sections of the beach that shared similar physical characteristics (Provanca et al. 1984).

Certain trends in nesting densities and apparent correlations with geophysical characteristics of the beach during the 1983 and 1984 surveys led the authors to analyze available nest density data from earlier years. This paper presents the combination of nesting data extracted from the 1979-81 turtle tagging projects as well as the 1983-84 crawl surveys that included physical measurements of the beach.

METHODS

Overall coverage of the various marine turtle studies at KSC extended from North lat. $28^\circ 24' 00''$ (Port Canaveral) to $28^\circ 47' 30''$ (Brevard/Volusia County line) (Fig. 2). In the years prior to STS launches (1973-80), tagging surveys were made from two to seven nights per week ending between 0100 and 0300 hours. The primary focus in these early studies was to obtain data on individual female turtles; since uniform coverage of the study area could not be met consistently, good nesting density estimates were often not attainable. Details of methods implemented during those years are found in Ehrhart (1979).

In 1979, general crawl data were reported for five beach zones or areas of varying lengths (Fig. 3). Area 1 extended 15 km along the KSC-Canaveral National Seashore (CNS) beach, from the south Volusia County line to Camera Pad 10. Area 2 extended 9 km from Camera Pad 10 to the Playalinda barricade. Area 3, 17 km in length,

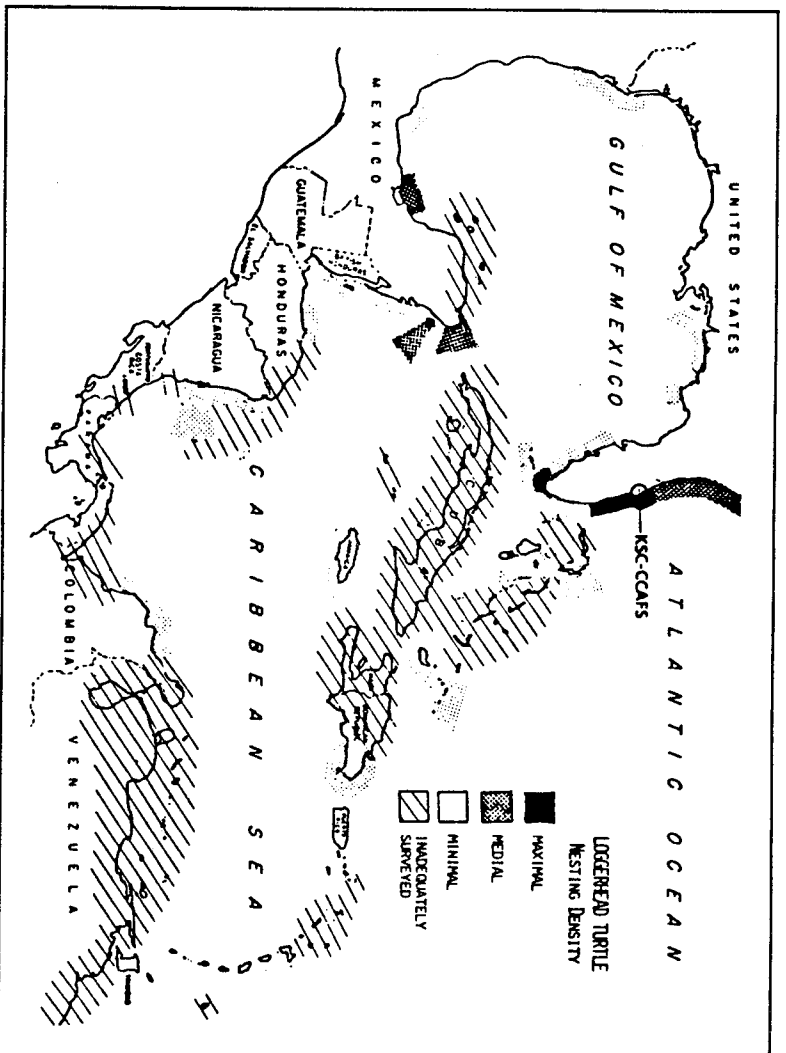


Figure 1—Distribution of loggerhead sea turtle nest densities in the western Atlantic Ocean and Caribbean Sea (after Carr et al. 1982).

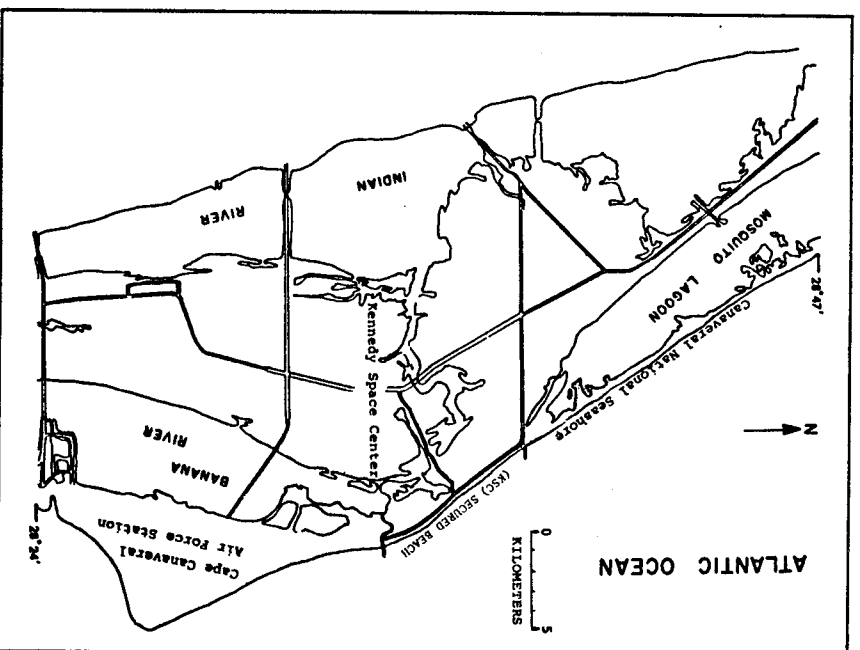


Figure 2—Marine turtle study beach 1973-84 extending along Kennedy Space Center and Cape Canaveral Air Force Station, Florida.

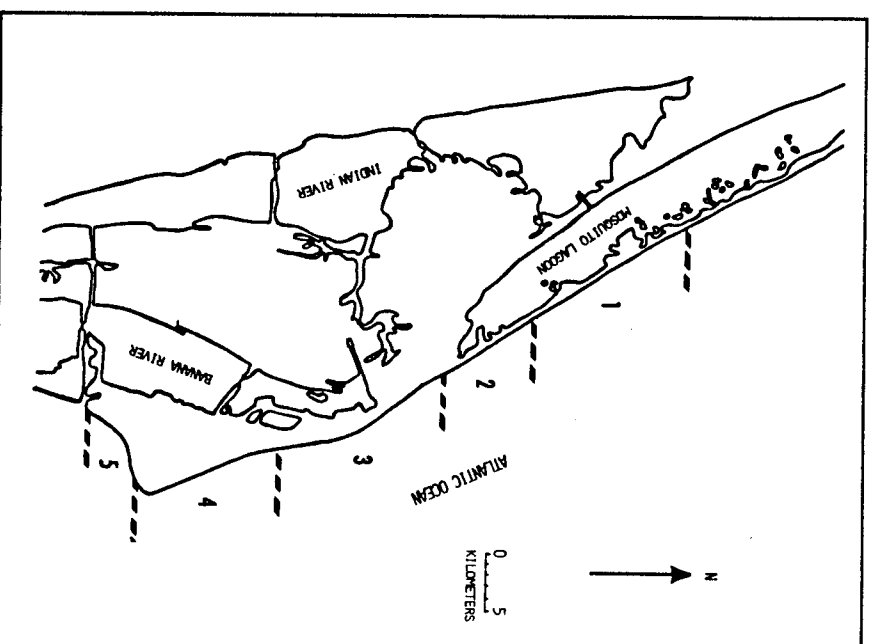


Figure 3—Location of the five major beach zones surveyed for sea turtle nests at Kennedy Space Center and Cape Canaveral Air Force Station, 1973-84.

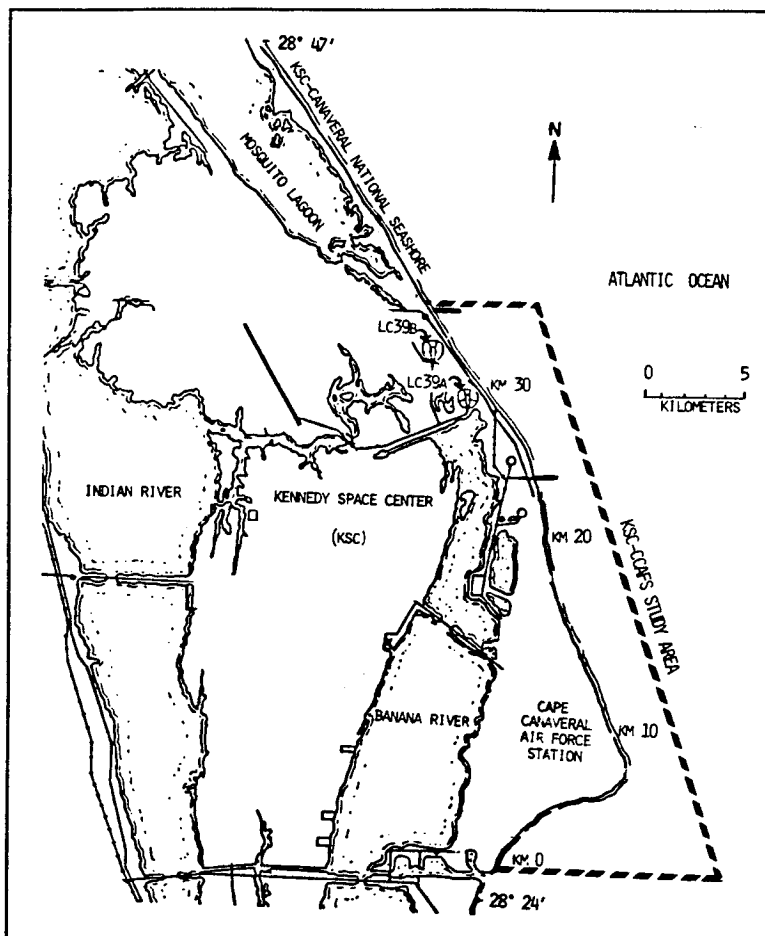


Figure 4—Location of the primary sea turtle nesting study area (km 0-34) along the Kennedy Space Center and Cape Canaveral Air Force Station Beach (1983-84).

was bounded by the Playalinda barricade and the riprap near Complex 34. South of this, Area 4 extended 11 km to Camera Road A. The southernmost zone, Area 5, extended 6 km from Camera Road A to Port Canaveral. More discrete (i.e., within 1 km) locations of the 1979 season crawls within each zone were not available. Consequently, mean nests per kilometer within each of the five areas were calculated by dividing the total number of nests/area by the number of kilometers within the area.

Research efforts were reduced in 1980 and 1981 but emphasized uniform coverage to yield better nest density estimates. However, due to logistical problems, some sections were surveyed less frequently than others. The 1980 and 1981 data, reported in 0.2-mile sections, were standardized to kilometers for comparison with data from 1983 and 1984 for the non-public or "secured" beach (km 0-34). Too few surveys were completed in 1981 at the km 0-7 beach area to make comparisons per kilometer. For each year, the number of nests observed within each kilometer was divided by the number of surveys conducted within the individual kilometer. This allows for within- and between-year comparability despite the lack of uniform coverage in 1980-81.

In 1983 and 1984, marine turtle monitoring was limited to morning "crawl counts" conducted by one or two observers on all-terrain motorcycles along the KSC-CCAFS beach, extending from Port Canaveral inlet (km 0) north 34 km to the southern boundary of Playalinda Beach (Fig. 4). False crawl and nesting data for that area north of km 34 were collected by CNS personnel during 1984. The KSC-CCAFS surveys were conducted after sunrise when most nesting activity had ceased. Data were collected during four con-

secutive days per week, or eight consecutive days per two-week period, from May through September. Eight survey days in 1983 and five in 1984 were considered tare days, and data gathered on those days were omitted from calculations. Tare days included the first day of an observation week when large numbers of "fresh" and "old" crawls were difficult to distinguish with confidence. The same observers were used both years to keep data collection methods consistent.

Data collected at each crawl included type (i.e., species, nest, false crawl), condition of nest (i.e., undisturbed, disturbed, depredated), location by kilometer, and comments regarding suggested source of predation. General conditions at the site of each crawl (i.e., body pit, thrown subsurface sand) were used to distinguish a true nesting crawl from a false crawl. Nests were not subjected to probing for verification of egg deposition. After notes were recorded at each crawl, tire tracks were made across the crawl near each nest in order to avoid recounts on the following day.

The 1983 and 1984 estimates were weighted by week to account for the change in intensity through the season. Total nests per kilometer for each week were estimated and weekly totals added to yield the overall estimates.

Quantitative field observations of physical beach parameters were limited to the area between the primary dune and the low tide mark. It is possible that basic oceanographic and shoreline data may also be utilized to assist in understanding the nesting distribution. When actual site-specific oceanographic measurements are not available, a certain amount of descriptive information can be extrapolated from inshore beach observations by applying basic beach process prin-

ciples. The beach face and berm can yield information about the nearshore and littoral zone, as they are very sensitive in response to the forces of currents, waves, and winds (Bascom 1964). Beach slope and width were measured at each kilometer in October of 1983 and in April, July, and October of 1984. To insure comparability, measurements were conducted within one hour of low tide. Slope was determined, using a Suunto clinometer with an accuracy of $\pm 1^\circ$, from the low tide line to the base of the primary dune. If no obvious dune was present, slope measurements were referenced to the point at which beach, sand, and vegetation interfaced. Beach width was measured at that distance along the sand surface, from the low tide line to the primary dune or first vegetation.

The penetrability or compactibility of the sand within each kilometer was considered a possible factor influencing the selection of nesting sites. The mean depth ($N=5$) of penetration of a metal rod (2 cm in diameter) using a standard weight (4.7 kg) was determined at each kilometer marker along the survey area. All penetrometer measurements were taken above the high tide line and seaward of the dune vegetation.

Nearshore bathymetry data were obtained from National Ocean Survey charts (NOAA 1979). Information on current patterns in the vicinity of Cape Canaveral was obtained from the literature.

RESULTS AND DISCUSSION

Species composition

In addition to the loggerhead turtles found here, two leatherback, *Dermochelys coriacea*, turtle nests were reported along this beach in 1983 and 1984, as well as one hawksbill turtle, *Eretmochelys imbricata*, that reportedly nested on the CNS portion of KSC in 1983 (R. Galipeau, Canaveral Natl. Seashore, pers. commun.). *Caretta caretta*, however, represent over 97.5% of the total crawls observed since 1973, with the west Caribbean green turtle, *Chelonia mydas*, comprising the balance. There is some fluctuation in the percentage of *C. mydas* each year as shown in Table 1.

Spatial and temporal trends

As stated earlier, the 1979 data were available only per beach subsection rather than on a per-kilometer basis. Figure 5 compares graphically the sea turtle nest densities from 1979 to 1984 in the five areas referenced in Figure 3. Although this graph shows considerably less variation than using data points for each kilometer, the groups of data for later years may be compared with the 1979 data. Area 4, which represents km 7-16 on CCAFS, consistently had the highest nesting densities, while Area 5 (km 0-6) had the lowest nest densities. All of these data are estimates, with the exception of Areas 1 and 2 in 1984, which are observed values based on surveys by CNS personnel during 95 mornings (almost all) of the 1984 season. All data suggest that nesting densities in 1980 were substantially lower over all areas than the other years, while 1983 densities were higher. The data also indicate that nesting densities in 1979, 1981, and 1984 were not statistically different.

More detailed data are available for 1980-84 (Fig. 6). It is apparent that the distribution of nests is not random. The 1980 plot in Figure 6 does not have the same strong signature (bimodal distribution) that is evident in the following years. It does suggest that highest nest densities occur between km 10 and km 16 (previously clumped within Area 4) and lowest densities from km

Table 1—Yearly variation in numbers of green turtles, *Chelonia mydas*, nesting at Kennedy Space Center-Cape Canaveral Air Force Station, expressed as the percentage of all marine turtles nesting there.

| Year | Percentage of turtles being <i>C. mydas</i> |
|------|---|
| 1976 | 0.9 |
| 1977 | 1.1 |
| 1978 | 2.1 |
| 1979 | 1.4 |
| 1980 | 2.5 |
| 1981 | 1.2 |
| 1983 | 1.8 |
| 1984 | 1.1 |

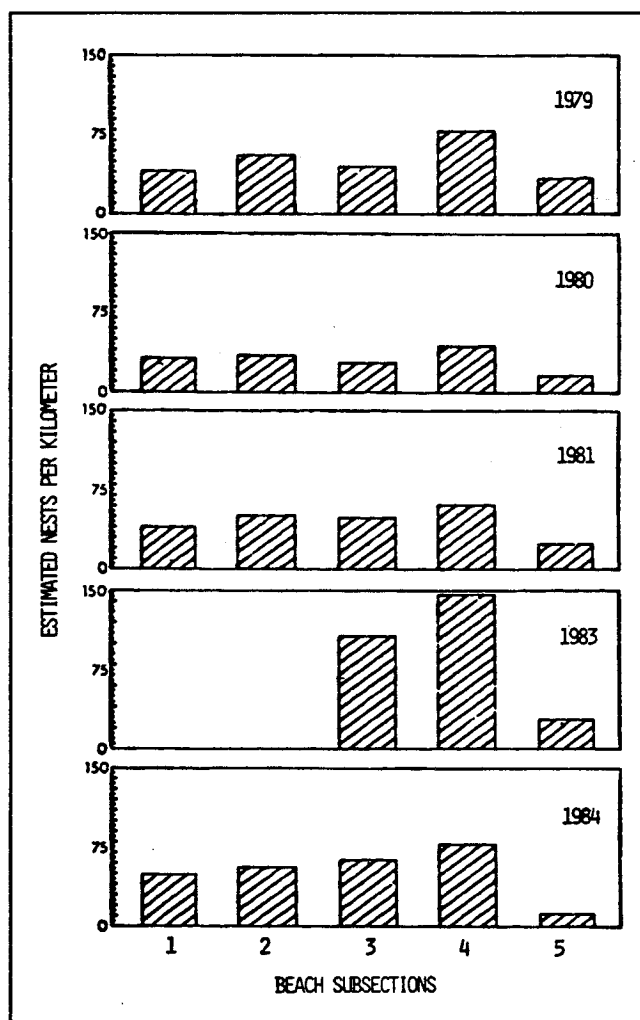


Figure 5—Comparison of nest densities within the five subsections of Kennedy Space Center-Cape Canaveral Air Force Station beach, 1979-84. No data were collected for zones 1 and 2 in 1983.

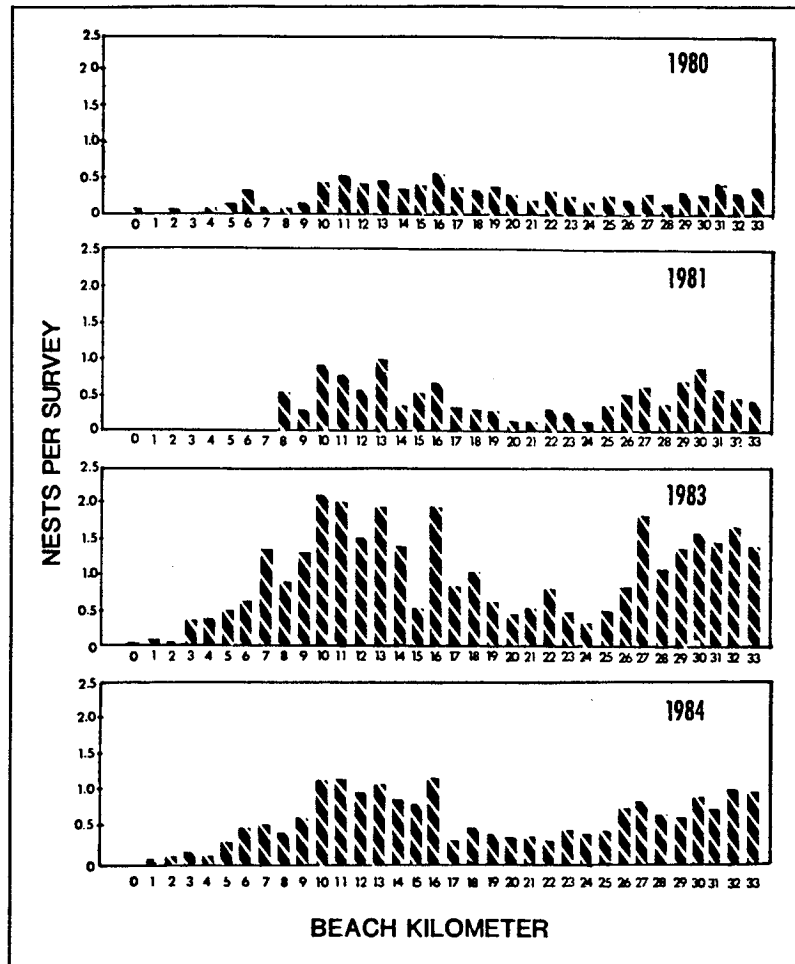


Figure 6—Spatial and temporal trends of sea turtle nesting at Kennedy Space Center and Cape Canaveral Air Force Station, 1980-84. Number of nests per survey effort at each km during the four survey years. Kilometers 0-33 extend from Port Canaveral north to Canaveral National Seashore. Insufficient data were collected for kms 0-7 in 1981.

0-9. Despite the reduced number of surveys in 1981, the 1983 trends reported by Provancha et al. (1984) are observable in the 1981-84 data. The general trend shows a very gradual increase in nest density as one moves north from Port Canaveral (km 0) until a peak occurs in nesting just north of the tip of Cape Canaveral, where it is most obvious between km 10 and km 16. After this peak, there is a significant ($P < 0.05$) decline in nest densities for about 8 km northward along the False Cape. North of False Cape from km 26 to km 33 in the vicinity of the shuttle launch complexes, another increase in nest densities occurs, though not quite as high as that seen to the south. The lack of sensitivity in the clumped data in Figure 5 is most apparent when comparing Figure 5's Area 3 with Figure 6, where Area 3 is found between km 17 and 33. The distinct low, then high, nesting densities seen within Area 3 are not visible in Figure 5. The relative change in number of nests between 1981 and 1983 is consistent with that reported by Harris et al. (1984) for 14 other beaches in Florida. 1983 appeared to be a "good" year for sea turtle nesting, while total emergences and number of nests in 1984 were notably lower. This was similar to observations in south Brevard County (Ehrhart, pers. observ.) and Hobe Sound (F. Lund, Univ Fla., pers. commun.).

Nests per kilometer

The mean nest density for 1984 in the high nest-density areas was 94 ± 19 nests/km, while the mean for the low nest-density area along the False Cape was 39 ± 10 nests/km. Using an approximate *t*-test

(Sokal and Rohlf 1969) performed when variances are unequal, these means are significantly different ($P < 0.05$). Much of the nesting data is summarized in Table 2. The highest nest densities occurred in 1983, with the mean for km 0-34 being 106 ± 65 nests/km, while 1984 had about half as many (56 ± 35 nests/km). The estimated nest/km range for the entire beach in 1983 was 2.4 (km 0) to 226 (km 10) while the observed range was 1-93 nests/km. The 1983 nesting was similar to the mean estimate of 116 nests/km at Hutchinson Island, Florida, during five sample years between 1971 and 1979 (Williams-Walls et al. 1983).

The years 1979 and 1984 were the most similar in comparing overall nest density estimates for km 0-34; 51 nests/km in 1979 and 56 nests/km in 1984. The total number of estimated nests along the beach in a given year ranged from a low of 833 in 1980 to 3,703 in 1983.

As stated earlier, the second peak in nesting densities occurred in the vicinity of the shuttle launch complexes between km 26 and 33. LC-39A is located approximately 0.7 km west southwest of km 29 and 30. The only shuttle launch that occurred during the summer of 1984 was on 30 August near the end of the nesting season. Two shuttle launches occurred during the 1983 nesting season and consequently the pad was illuminated from 26 May to 18 June and from 2 July to 30 August, for a total of 84 nights or 79% of the census period. Based on nest distributions over the season, the data suggest that nesting females were not avoiding the beach areas where activities (i.e., lights) from LC-39A might be expected to have the most impact. In fact, this subsection of beach

Table 2—Summary of marine turtle nesting data collected 1979-1984 at Kennedy Space Center and Cape Canaveral Air Force Station.

| Year | Survey area (km) | Nests Est. (Observ.) | False Crawl Est. (Observ.) | NFCR* | Total Emergence Est. (Observ.) | Number of surveys | Mean nests/km Est. (Observ.) |
|---------------------|------------------|----------------------|----------------------------|--------|--------------------------------|-------------------|------------------------------|
| 1979 ¹ | 0 - 34 | 1,728 (1,200) | 1,713 (143) | 1:0.99 | 3,441 (1,343) | 74 | 51 (35) |
| 1980 ¹ | 7 - 34 | 833 (683) | — | — | — | 64 | 30 (24) |
| 1981 ¹ | 7 - 34 | 1,265 (417) | 1,080 (265) | 1:0.85 | 2,345 (682) | 29 | 45 (14) |
| 1983 ² | 0 - 34 | 3,703 (1,532) | 2,420 (999) | 1:0.65 | 6,123 (2,531) | 53 | 106 (45) |
| 1983 ² | 7 - 34 | 3,506 (1,451) | — | — | — | 53 | 125 (51) |
| 1983 ² | 10 - 34 | 3,129 (1,295) | — | — | — | 53 | 130 (53) |
| 1984 ^{2,3} | 0 - 34 | 2,078 (1,141) | — | — | — | — | 56 (33) |
| 1984 ^{2,3} | 7 - 34 | 2,004 (1,088) | — | — | — | — | 71 (38) |
| 1984 ² | 10 - 34 | 1,914 (1,036) | 1,332 (720) | 1:0.70 | 3,248 (1,756) | 65 | 82 (44) |

¹ = Nightly tagging/Ehrhart

² = Morning crawl counts/Provancha

³ = Morning crawl counts/CCAFA-FWS

*NFCR = Nest to false crawl ratio

Dashes indicate no data available.

still appears to be highly suitable for nesting and is part of a section that is "preferred" by nesting females. No hatchling orientation landward (towards LC-39A) was observed in 1983 or 1984.

False crawls

A large number of false crawls relative to nesting crawls on a given stretch of beach might indicate a constant source of disturbance in the vicinity and/or that the females are selecting nests sites after emergence. With few exceptions, the false crawl densities followed the same spatial trend as the nesting densities. The low nest-density area along the False Cape corresponded to low false-crawl densities, suggesting that females were "selecting against" this area prior to emergence.

The ratio of nests to false crawls (nfc) along the beach for the various years is reported in Table 2. In 1983 and 1984 false crawls above and below the high tide line were added together to yield a total for each km. The mean nfc ratio was 1:0.7 for the two years, varying from 1:0.2 to 1:14.2. The lowest nfc ratio (1:14.2) occurred in 1983 at km 2 near Port Canaveral. The beach sections in the vicinity of LC-39A (km 29, 30, 31) had nfc ratios slightly lower than the mean in 1984 at 1:1.4, 1:0.85, and 1:0.95, respectively. In 1983, km 29 and 31 had nfc ratios at the mean while km 30 had an nfc ratio below the mean at 1:1.08. Whether or not these data can be used as indicators of habitat suitability change is questionable. In areas where obvious nesting obstructions occur, such as riprap, the nfc ratio is typically below the mean.

Numbers of nesting females

It was not rare to find a female nesting after sunrise in 1983 and 1984. This agrees with observations by Fritts and Hoffman (1982) of diurnal nesting in Brevard County. The data from 1979-81 may represent relatively low estimates as data were generally collected before 0300 hours and late morning crawls were not included.

Determining the actual numbers of females nesting on the beach using morning crawl surveys is impossible. The mean within-season renesting frequency is subject to variation from year to year (Ehrhart 1979; Carr et al. 1982; Richardson and Richardson 1982; Hughes 1982). However, by applying the renesting mean of 2.5 for the KSC loggerheads derived by Ehrhart (1979), an estimate can be obtained.

Assuming there are 2.5 nests/female each season, estimates of 3,703 nests in 1983 and 2,078 nests in 1984 yielded 1,481 and 831 females nesting in the KSC-CCAFA study area in 1983 and 1984, respectively.

Physical parameters

Mortimer (1982) and Caldwell (1959) attempted to correlate nesting density with various physical characteristics of the beach and near-shore zone as well as other environmental factors. Caldwell (1959) reported no correlation between nesting activity and the stage of the moon or tide, and concluded that physical features of the beach were apparently the most important factors in determining the degree of nesting activity. He described six beach types characterized by several parameters and concluded that turtles preferred to nest on high beaches backed by rounded dunes. Mortimer (1982) concluded that sand types were probably less important in the selection of nesting beaches by green turtles than were the slope and offshore configuration of the beach, although slope measurements were not reported. Mortimer successfully correlated beach length with nesting density ($r=0.92$) at Ascension Island. Williams-Walls et al. (1983) were unable to consistently correlate beach width and sub-tidal characteristics with nesting density at Hutchinson Island.

Least squares curve fit analyses (LSCFA) of the 1983 data demonstrated that nesting densities did increase with beach slope ($r=0.83$) but also that the error of regression was directly related to slope. The sand in these high nest-density sections also appeared to be coarser and the surface less resistant to penetration. Komar (1976) and Bascom (1964) explained that coarse sand beaches are generally steeper in slope than fine sand beaches. The characteristic slope of a beach face is the result of several semi-independent factors acting together, including grain size, wave energy level, wave steepness, sediment sorting, water table level in the beach, and tidal stage. These data are involved in the general description of high-energy and low-energy beaches. Sections of the KSC-CCAFA seashore that are high-energy beaches were found to correspond with highest nest densities, and low-energy beaches corresponded to low nest densities in the vicinity of the False Cape.

The beach face slopes measured in July 1984 (during the peak of the nesting season) ranged from 3° to 12.5° and the width measured 25 to 74 m. Figure 7 shows the relationship between beach

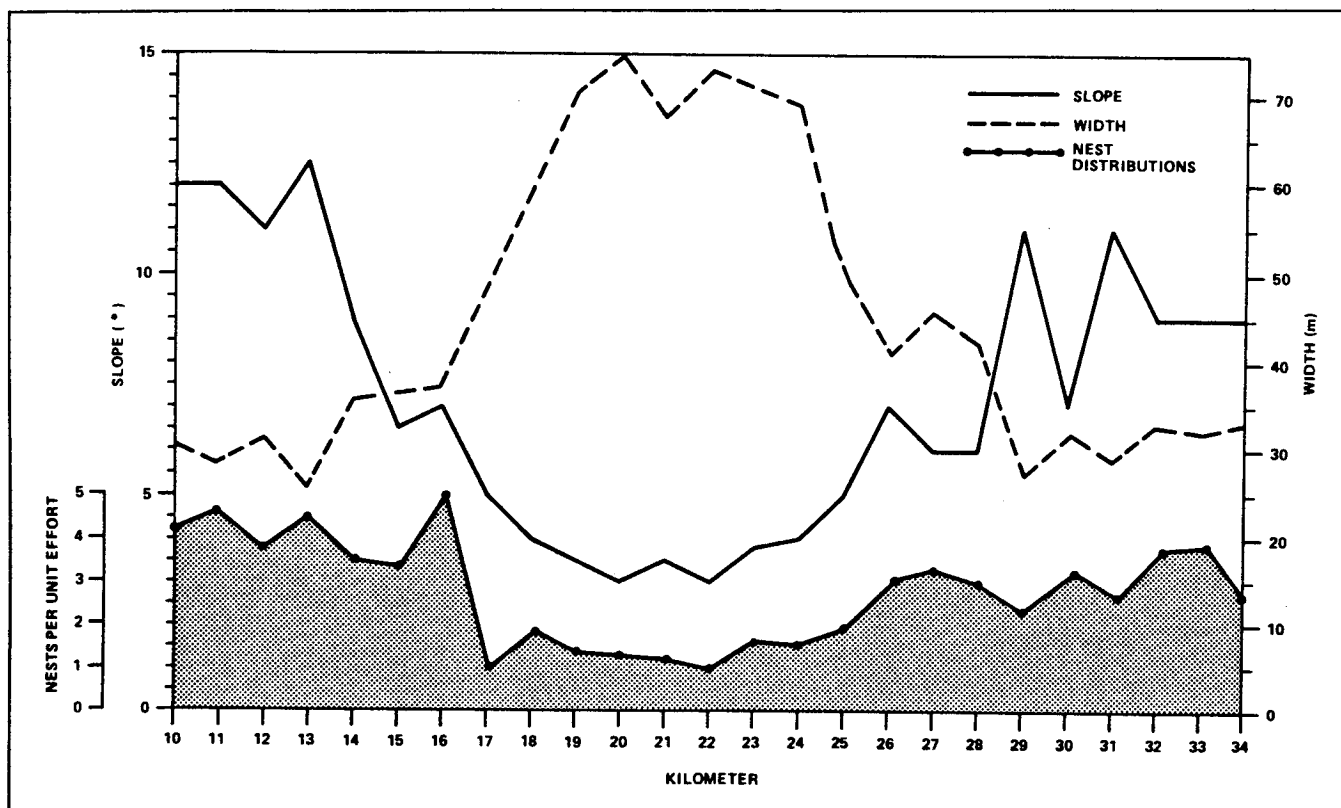


Figure 7—Relationships between sea turtle nest densities, beach slope, and beach width at Kennedy Space Center-Cape Canaveral Air Force Station, July 1984. Nests per survey represent relative nest density.

slope, width, and nesting densities at KSC-CCAFA. The LSCFA r -value for July 1984 was 0.81 for slope and nest density, while the correlation of slope to total emergences was higher ($r=0.86$). The slope and width are highly correlated (inversely) to one another as expected. Total emergence was negatively correlated ($r=-0.79$) with beach width. Thus, females appear to select nesting areas prior to emergence. When the false crawl/total emergence ratio was compared with beach slope, no correlation was found.

The sand resistance or compaction and nesting densities for each km are shown in Figure 8. The data for kms 13, 14, and 15 deviate from the general trend for the entire beach and cannot be explained. LSCFA showed significant but low correlation for these parameters ($r=0.54$). Sand resistance measures the relative ease of penetrating the sand which may in turn relate to grain size and sorting (two parameters which were not measured). The mean sand penetrability for the high nest-density sections was 11.1 ± 2.0 (cm) while that for the low nest-density sections was 8.4 ± 1.0 (cm). Bascom (1964) and Komar (1976) reported profile characteristics that are normally associated with the characters measured at our two beach types (high nesting density vs. low nesting density), and thus we can form an extrapolated but potentially more insightful description of a "preferred" nesting beach along the KSC-CCAFA shore. Such a description is outlined in Table 3.

The depth contours within 3 nautical miles of the 1984 study beach (km 10-34) are shown in Figure 9. It is striking to note that the kms with low nest densities are concentrated along the False Cape and delineated by a long, trenchlike 35-ft (10.7 m) isobath that is approximately 0.5 km east of the False Cape and bound to the east by Chester Shoals. A marked contrast is seen in the area immediately south (just north of the tip of Cape Canaveral). This section

has consistently had the highest nest densities within the study area. The isobaths are serrated and the profile is a gradual seaward slope not reaching 35-ft depths within the first nautical mile. The intermediate nest densities occur to the north of the False Cape, on KSC, where a 35-ft isobath occurs relatively nearshore but is highly branched. Another perspective is shown in Figure 10. Depth profile comparisons were made for the low and high nest-density areas by plotting the profile from a point within a representative kilometer from each area type. Kilometer 10 represents the high nest-density area, km 23 represents the low, and km 29 represents the medium-to-high nest-density area. Notice the relatively steep slope of km 23 when compared with km 10. This would fall into Komar's (1976) category of "less shallow nearshore" listed in Table 3.

Literature reviews and personal communications with meteorologists and oceanographers familiar with the southeastern U.S. coast revealed that very little detailed information pertinent to the study area has been collected over the last 20 years. Most of the nearshore data from other areas cannot be assumed to relate to the study area, especially considering local influences from the projection of the Cape itself. A special study, similar to that done with green turtles at Tortuguero (Meylan 1978), would have to be implemented to obtain the data necessary to address the role of currents on sea turtle movement to Cape Canaveral nesting sites.

The data that have been collected in the vicinity of Cape Canaveral have shown that it is located in a "meteorological transition zone" with an offshore bathymetry of complicated shoals and sediments ranging from silt to hard reef formation (USAEC 1970). The continental shelf lies approximately 50 km east of the Cape. Blanton et al. (1981) reported topographically induced upwelling just north of Cape Canaveral. They reported that the regions where

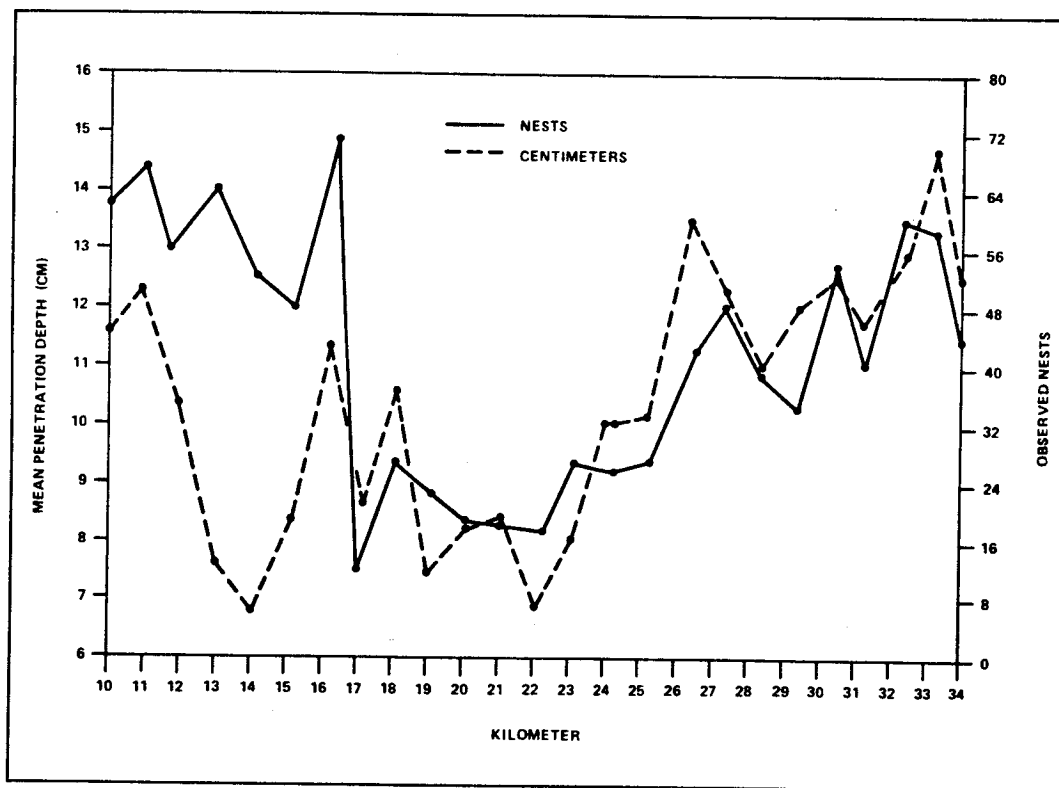


Figure 8—Comparison of nest densities and relative sand penetrability or resistance (cm) at km 10-34, Kennedy Space Center-Cape Canaveral Air Force Station, 1984.

Table 3—Beach profile characteristics associated with high and low nest-density beaches at Kennedy Space Center-Cape Canaveral Air Force Station in 1984. Associations made by actual measurement (m), visual observation (o), or extrapolations (E) from Komar (1976).

| High nesting (km 10-17 and 26-33) $\bar{x} = 94 \pm 19$ nests/km | Low nesting (km 18-24) $\bar{x} = 39 \pm 10$ nests/km |
|--|---|
| ^m Steep slope $\bar{x} = 9 \pm 2^\circ$ | ^m Mild slope $\bar{x} = 4 \pm 0.9^\circ$ |
| ^m Narrow beach $\bar{x} = 33 \pm 5.6$ m | ^m Wide beach $\bar{x} = 64 \pm 9.9$ m |
| ^o Coarse sand | ^o Fine sand |
| ^o Distinct berm | ^o No distinct berm |
| ^o Shallow nearshore | ^o Less shallow nearshore |
| ^E High percolation rate | ^E Low percolation rate |
| ^E Low wave-energy level | ^E High wave-energy level |
| ^E Low wave steepness | ^E High wave steepness |
| ^E Few or no longshore bars | ^E Many longshore bars |
| ^E Onshore sediment transport increased | ^E Onshore sediment transport decreased |

isobaths diverge (north of capes and shoals) "force the flow of shelf water to change vorticity and induce upwelling." Atkinson and Targett (1983) found that fish concentrations were highest in areas of pronounced upwelling off Cape Canaveral, south Georgia, and South Carolina during their survey which extended from Cape Canaveral to Cape Hatteras. Thus, the waters off Cape Canaveral are apparently highly productive and constitute what might be referred to as a biological "hot spot."

The concentrated biological activity in the area could provide several advantages to turtles. It may serve as a strong signature that assists in locating the east central Florida beaches. If nesting females feed in the nesting habitat, this area should provide excellent foraging grounds. The area would simultaneously have possible disadvantages with likely increased concentrations of predators and increased incidental conflicts with fishermen.

Nontidal drift experiments off Cape Canaveral were conducted by Woods Hole Oceanographic Institution during 1962. The experiments showed that a northerly nontidal current is present from November to June and a southerly nontidal current exists from July to October (Bumpus 1964). This reversing nature was said to increase the possibility that "introduced materials" will remain in the area. This idea was supported by Leming (1979), who reported that the projection of the Cape causes "interruption and eddying" which in turn cause repetitive settling of scallop larvae off Cape Canaveral. In early spring, Bumpus (1964) found little stratification and no dynamic current within 16 km of shore. A southerly component next to the shore was found that extended as far south as the eastern tip of the Cape and then extended offshore. A northerly component ran along Cocoa Beach and then extended offshore at Port Canaveral south of the Southeast Shoal (Fig. 11). Based on this description, one might speculate that if nesting sea turtles are

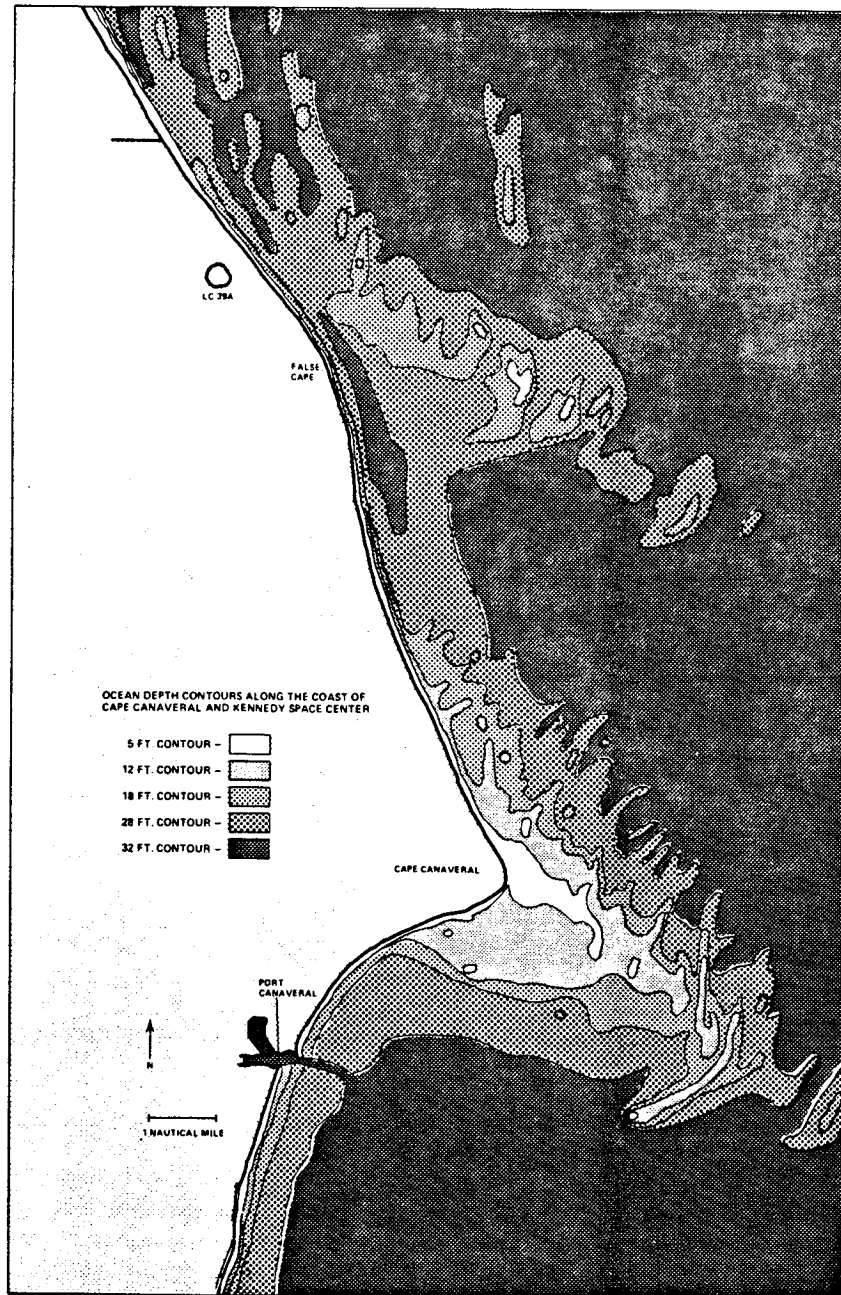


Figure 9—Nearshore contours along the Kennedy Space Center-Cape Canaveral Air Force Station beach within 3 nautical miles.

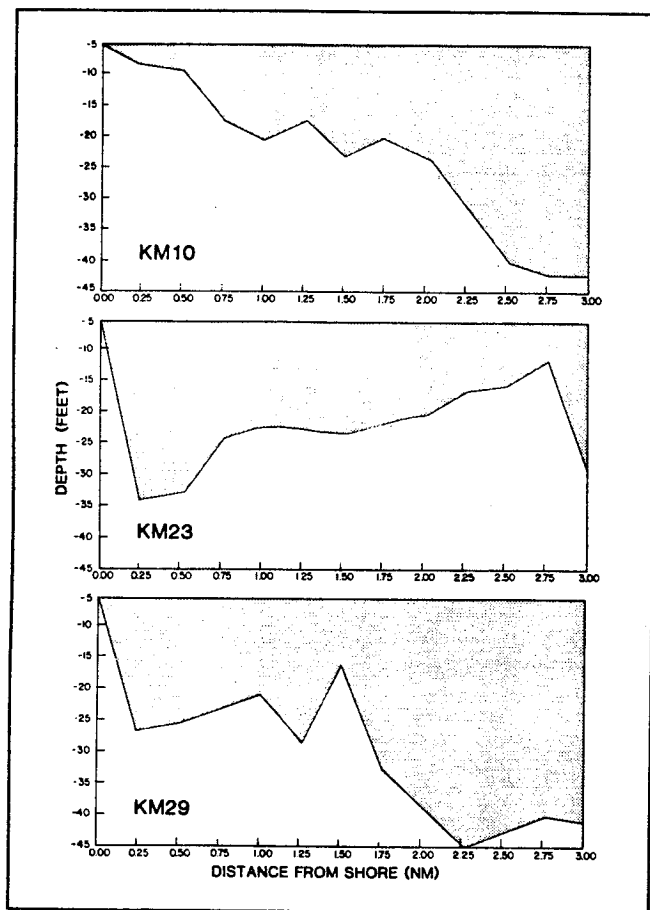


Figure 10—Depth profiles for high and low nest-density beaches at Kennedy Space Center-Cape Canaveral Air Force Station, where km 10 represents high, km 29 represents medium, and km 23 represents low nest-density beach.

strongly influenced by such currents, it could explain the relatively low numbers of crawls found south from the tip of the Cape to Port Canaveral. This is not to negate the possibility that the high level of human activity at and south of the Port may be a stronger influence on nesting. These current patterns also lead one to wonder what effect they have on local hatchlings during the migration away from the beaches.

SUMMARY

The 1979-84 sea turtle nest density estimates for the KSC-CCAFS range from 30 nests/km in 1980 to 106 nests/km in 1983. An estimated 1,481 (1983) and 831 (1984) females nested on the secured or "non-public" KSC-CCAFS beach (km 0-34). The nesting distribution was not random and was repeated each year, with the highest nest densities found in two peaks. One peak was seen in

an 8-km section of KSC beach that was in the vicinity of the STS launch pads; the other consistently higher nest density peak was seen at a 7-km section of beach originating just north of the easterly tip of Cape Canaveral. The two peaks were separated by a relatively low nest-density area in the region of the False Cape. A second low nest-density area repeatedly occurred at the south end of the study area near Port Canaveral. The data indicate that the beach near LC-39A is part of a section that is suitable for nesting and could be referred to as "preferred," as there were no obvious indications of avoidance by nesting females.

Total emergences and nest densities were correlated to beach slope and width in most cases. Steeply sloped beach sections had higher nest densities ($r=0.83$) and higher total emergences ($r=0.86$). Sand compaction or resistance showed a statistical correlation of ($r=0.54$). Offshore contours may also play a part in nesting beach site selection. A gradual increase in depth seaward defines the depth contours for the beach section with the highest nest densities (and steep beach face slope). The low nest-density area bordered by the two peaks in nesting was characterized by a nearshore "trough" or drop off, bordered to the east by shoals.

As shown by Bascom (1964) and Komar (1976), beach slope is highly correlated to a variety of offshore semi-independent factors. Because of the slope and total emergence relationship, one would conclude that nest site selection is determined prior to emergence and is influenced by one or more offshore parameters that are correlated to steep beach slope (i.e., depth contours, wave energy). These offshore characteristics appear to be cueing KSC-CCAFS female loggerhead turtles to their nest sites which coincidentally are steeply sloped beaches, or perhaps the turtles are using the offshore cues to "select for" a steeply sloped beach.

The current patterns in the vicinity of Cape Canaveral may motivate sea turtles to utilize this section of the Brevard County coastline rather than immediately south or northward. The eddying created by the currents may also play a role in inhibiting emergences just south of the tip of Cape Canaveral.

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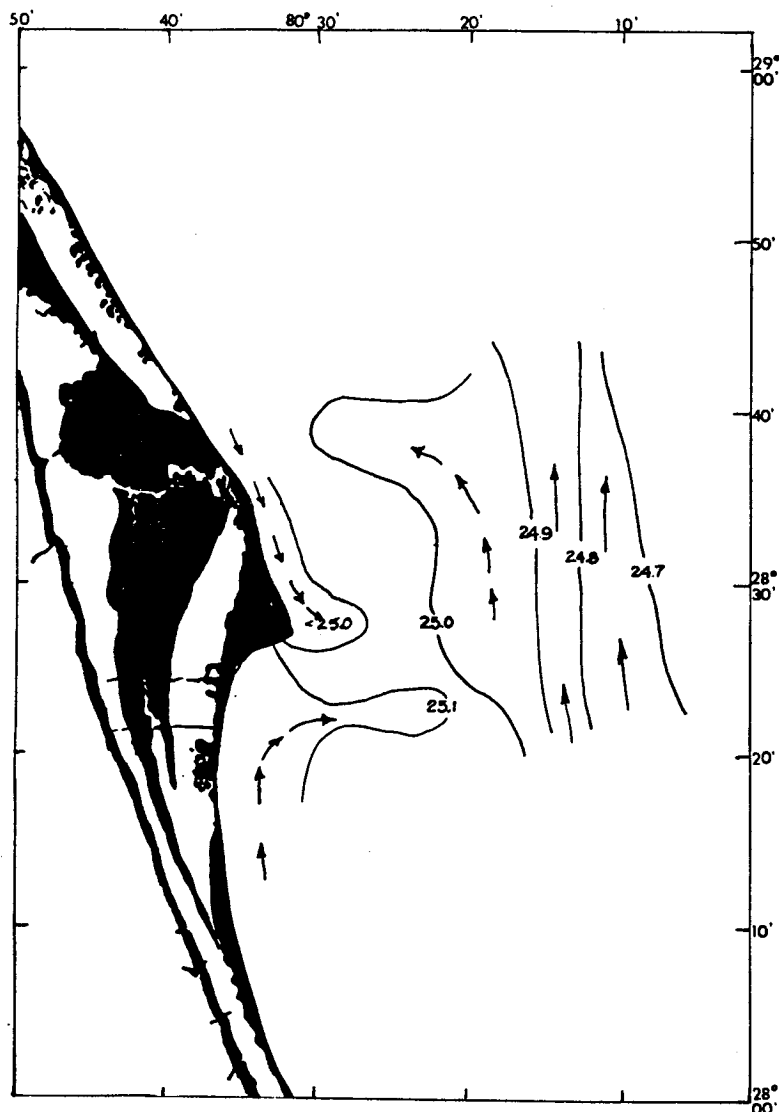


Figure 11—A plot of the distribution of O_2 at 10 meters in the vicinity of Cape Canaveral, Florida, spring 1962 (from Bumpus 1964).

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